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UNIVERSITY OF HOUSTON HOUSTON, TEXAS

UHMIE
PROGRAM DESCRIPTION
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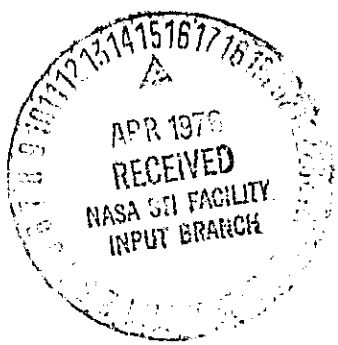
REPORT #48 OCTOBER 1975



PREPARED FOR
EARTH OBSERVATION DIVISION, JSC
UNDER
CONTRACT NAS-9-12777

HOUSTON, TEXAS 77004

UHMLE - Program Description
User Guide

October, 1975

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University of Houston

Report #48

Contents

I. Introduction

This program computes maximum-likelihood estimates for the general normal mixture. That is, MLE estimates are found for α_k, μ_k, Σ_k, k=1,...,M in the model

$$p(x) = \sum_{k=1}^{M} \alpha_k p_k(x_i \mu_k, \Sigma_k)$$

where $\{p_k\}$ are multivariate (N-dimensional) normal density functions with means μ_k and covariance Σ_k, and $\{\alpha_k\}$ are the mixing proportions. The algorithm used is described in detail in [1]. Simply stated, it consists of solving the following fixed point equations. For ϵ_α, ϵ_μ, ϵ_Σ arbitrary positive constraints less than two (called iteration weights), find at each iteration new parameter values (indicated by primes) using previous values (without primes) from the following system of equations. For a sample of LTOT observation vectors $x_1,\ldots,x_{LTOT}$ the iteration equations are

$$\alpha_k' = (1-\epsilon_\alpha)\alpha_k + \epsilon_\alpha\{\frac{\alpha_k}{LTOT} \sum_{j=1}^{LTOT} \frac{p_k(x_j)}{p(x_j)}\}$$

$$\mu_k' = (1-\epsilon_\mu)\mu_k + \epsilon_\mu\{\frac{1}{LTOT} \sum_{j=1}^{LTOT} x_j \frac{p_k(x_j)}{p(x_j)}\}$$

$$\Sigma_k' = (1-\epsilon_\Sigma)\Sigma_k + \epsilon_\Sigma\{\frac{1}{LTOT} \sum_{j=1}^{LTOT} (x_j-\mu_k)(x_j-\mu_k)^T \frac{p_k(x_j)}{p(x_j)}\}$$

for k = 1,...,M.

The data vectors must be read onto a direct access device, prior to execution of UNIMLE. The data is stored sequentially by vector (pixel) in any format, specified by the reader.

The number of data vectors in core is flexible. Hence only L (possibly L = 1) vectors at a time may be read into core, in order to minimize the program size, or all data vectors may be stored in core, in order to eliminate I/O time. An intermediate choice is usually called for in large data sets.

The program allows the user to fix any subsets of the mixture parameters (e.g. hold the Σ's constants while iterating on the α's and μ's, etc). This fixed set may be redefined at various times in the iteration process (i.e. when the α's and μ's converge for fixed Σ, then fix μ's and iterate on α's and Σ's). The Σ's may be assumed to be diagonal or full symmetric covariance matrices. There is considerable time saved in computing the likelihoods if the diagonal form is specified. Hence in the early iterations the diagonal assumption might be used, changing over to the full covariance mode later in the iteration process for a more refined solution. This flexability allows the user to chose the sequence of parameter configurations in the iteration process which he feels will optimize the computation time required as well as possibly avoid convergence to suboptimal local maxima of the likelihood function.

References

[1] B. C. Peters and H. Walker - An Iterative Procedure for Obtaining Maximum-Likelihood Estimates of the Parameters for a Mixture of Normal Distributions. July, 1975

[2] B. C. Peters and H. Walker - Addendum to "An Iterative Procedure for Obtaining Maximum-Likelihood Estimates of the Parameters for a Mixture of Normal Distributions". September, 1975

II. PROGRAM ELEMENTS

MLO2 - Main driver. Reads job control parameters and sets up data arrays.

SUPER - Reads initial values for mixture parameters. Reads successive sets of iteration control parameters and supervises the iteration method prescribed.

ITRAMS - Computes updated values for α,μ,Σ for each iteration. (α may be fixed.)

ITRAM - Computes updated values for α,μ, for each iteration with Σ fixed. (α may be fixed).

ITRAS - Computes updated values for α,Σ, for each iteration with μ fixed. (α may be fixed).

ITRA - Computes updated values for α for each iteration with μ,Σ fixed. In this case the component likelihoods are computed only once and stored on disk in a temporary data set.

QUAD - Computes the quadratic forms for either full or diagonal covariances.

PRINT - Prints appropriate results at each iteration.

CHSLKY - Computes the inverse covariance matrix and determinant by the Cholesky decomposition method.

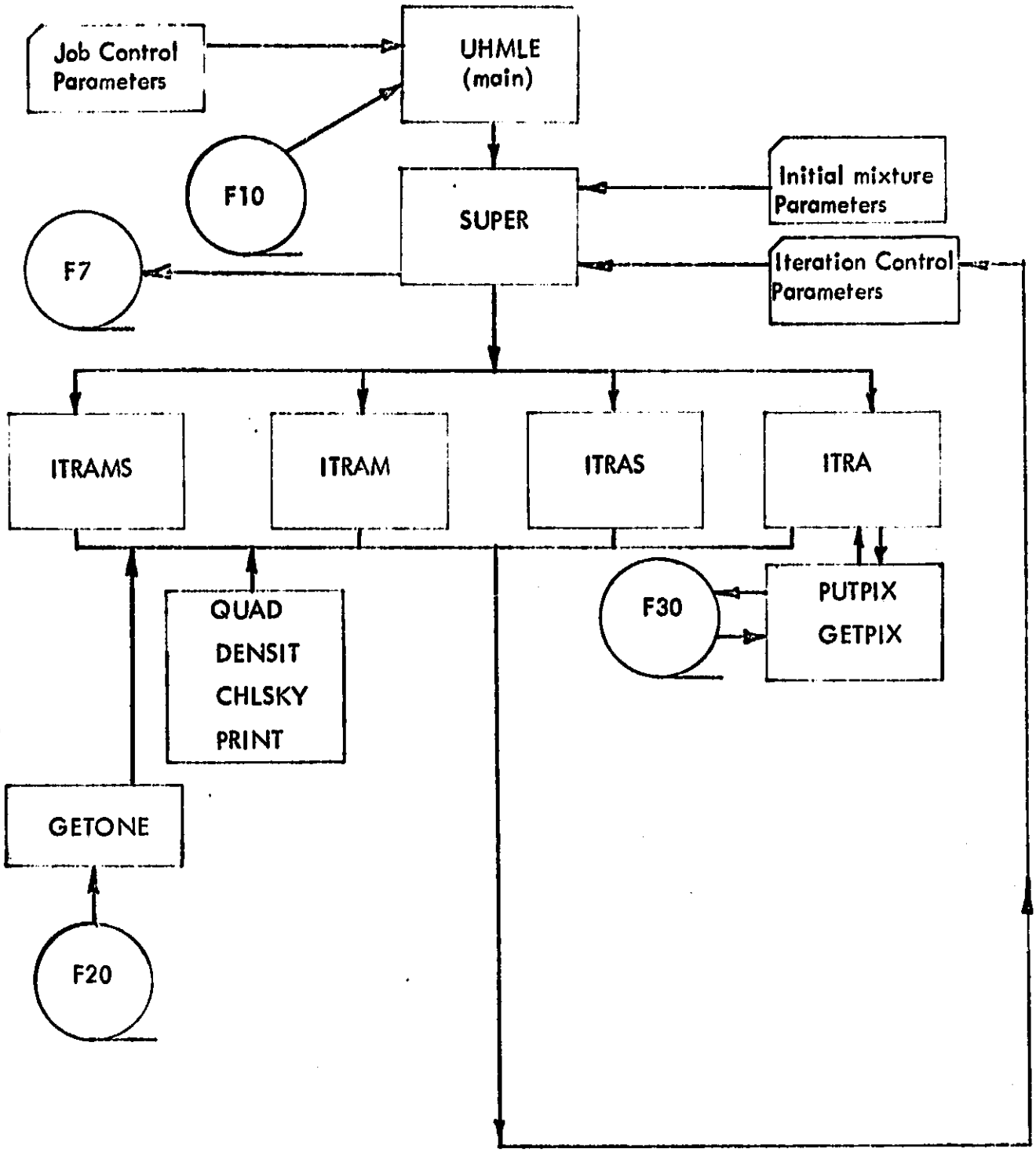
GETONE - Monitors transfer of data from disk to core. This activity is transparent to the ITR prefixed routines.

PUTPIX - Monitors storage of the component likelihoods onto disk. Used by ITRA only.

GETPIX - Monitors retrieval of the component likelihoods from disk. Used by ITRA only.

DENSIT - Computes the posterior probability for all classes for each observation (pixel).

UHMLE FLOW DIAGRAM



III. VARIABLE DESCRIPTIONS

1. Job Control Parameters

N - Number of channels (dimension of measurement space).

M - Number of classes

L - Number of observation vectors in core at one time.

N2 - N(N+1)/2

NN - N^2

NL - N×L

ML - M×L

LTOT - Total number observations vectors in the data set.

RUNID - A four character run identification code.

F7 - Fortran unit number for output signatures.

F10 - Fortran unit number for input of LTOT.

F20 - Fortran unit number for direct access file containing date vectors.

F30 - Fortran unit number for direct access temporary file containing component likelihoods.

ICORE - Upper limit for the dimension (single precision words) of the blank common work data array.

FMT(18)- Format for the input data vectors read by GETONE.

. The values of F7, F10, F20, F30 are presently set to 11, 12, 13, 14 respectively. In order to alter these, change cards UHML1480-510.

. Presently N must be 30 or less and M must be 20 or less. L is limited by ICORE. To change these limitations, the Common/ITRWRK/ must be altered in <u>each</u> routine.

. Presently ICORE < 16000. To change this, alter cards UHML1450-60 and UHML2010.

. ICORE = M(6+4N + 3N2 + L) + N(6N+L)

2. Iteration Control Parameters

IFLAGA	- 1	means to iterate on alpha.
	0	means to hold alpha fixed.
IFLAGM	- 1	means to iterate on means.
	0	means to hold the means fixed.
IFLAGS	- 1	means to iterate on the sigmas.
	0	means to hold the sigmas fixed.
MODES	- 1	general symmetric covariance.
	2	diagonal covariance.
ITLIM	-	maximum number of iterations allowed for this iteration phase.
TOLA	-	convergence tolerance for ALPHA
TOLM	-	convergence tolerance fo MU
TOLS	-	convergence tolerance for SIGMA
EPSA	-	iteration weight for ALPHA
EPSM	-	iteration weight for MU
EPSS	-	iteration wieght for SIGMA
ITRPNT	-	1 means to print results at each step of the iteration.

ALPH(K)	CURRENT VALUE OF PROPORTION ESTIMATE FOR KTH CLASS
ALPHO(K)	LAST ("O" IS FOR OLD) VALUE OF PROPORTION ESTIMATE FOR KTH CLASS
INDM	INDEX FOR VECTOR OF LENGTH M X N CONSISTING OF M MEAN VECTORS OF LENGTH N SIDE-BY-SIDE
MU(INDM)	CURRENT VALUE OF COMPONENT OF THE "LONG" MEAN VECTOR
MUO(INDM)	LAST VALUE OF COMPONENT OF THE "LONG" MEAN VECTOR
INDS	INDEX FOR VECTOR OF LENGTH M X N2 CONSISTING OF M "LOWER TRIANGULAR HALVES" OF N X N COVARIANCE MATRICES EACH ONE OF THESE M IS INDEXED IN THE FOLLOWING ORDER 1 2 3 4 5 6 7 8 9 10 . . . . N2
SIG(INDS)	CURRENT VALUE OF A COMPONENT OF THE "LONG" CO-VARIANCE MATRIX
SIGO(INDS)	LAST VALUE OF A COMPONENT OF THE "LONG" COVARIANCE
INDSS	INDEX FOR SIGIN
SIGIN(INDSS)	CURRENT VALUE OF A COMPONENT OF THE INVERSE OF A COVARIANCE MATRIX INDEXED IN THE SAME WAY AS THE COVARIANCE MATRIX. FOR THIS INVERSE WE HAVE MULTIPLIED THE DIAGONAL ELEMENTS BY ONE HALF FOR EFFICIENCY OF LATER COMPUTATIONS.
PIXK(K)	KTH COMPONENT DENSITY FUNCTION
P	MIXTURE DENSITY FUNCTION
R	RATIO OF COMPONENT DENSITY TO MIXTURE DENSITY
X(K)	KTH COMPONENT OF OBSERVATION VECTOR
XM(K)	KTH COMPONENT OF OBSERVATION VECTOR MINUS KTH COMPONENT OF CLASS MEAN VECTOR
XBUFF	N X L BUFFER ARRAY OF OBSERVATIONS...DATA IN CORE AT ONE TIME
PXBUFF	M X L BUFFER ARRAY OF LIKELIHOOD (ONLY USED BY ITRA)
XLP	N X N TRIANGULAR FACTOR FROM SUBROUTINE CHLSKY
XTEMP	N X N WORK MATRIX FROM SUBROUTINE CHLSKY
CFI	N X N INVERSE MATRIX PRODUCED BY SUBROUTINE CHLSKY RECALL WE MULTIPLY DIAGONAL ELEMENTS BY 1/2
EPSA	ITERATION WEIGHT FOR ALPHA
EPSM	ITERATION WEIGHT FOR MU
EPSS	ITERATION WEIGHT FOR SIGMA
Q	ONE-HALF VALUE OF QUADRATIC FORM COMPUTATION
CALFLG	CONTROL FLAG FOR CALLING SUBROUTINE GETONE
DELA	SUP OVER ALL CLASSES OF $\lvert ALPH(K) - ALPHO(K) \rvert$
DELM	SUP OVER ALL CLASSES OF SUP OVER ALL COORDINATES OF $\lvert MU(K) - MUO(K) \rvert$
DELS	SUP OVER ALL CLASSES OF SUP OVER ALL I & J OF THE
IPT	POINTER IN GET/PUT ROUTINES
ITRCT	COUNTER FOR NUMBER OF ITERATIONS

IV. FILE DESCRIPTIONS

1. F10 - LTOT Unit, fortran unit 12.

This file contains only one data field, LTOT the number of observation vectors in the intermediate image data set residing on unit F20. This is a one record file with format (I8,72x). LTOT is usually computed from tape to disk in a prior job step. If fortran unit 5 is assigned to F10 then this must be the first card in the data input stream.

2. F20 - Intermediate image data set, fortran unit 13.

This file contains the observation vectors (pixels) formatted according to FMT. This data set should reside on a direct access device (disk) since this file is rewound at each iteration (except when iterating on α only in ITRA). The data set may contain any number of channels. A subset may be selected by specifying the format FMT. The file is accessed in the GETØNE routine. Each logical record is an N-dimensional vector or pixel

Rec	Pixel
1	Channel 1, Channel 2;..., Channel N
2	Channel 1, Channel 2,..., Channel N
.	
.	
.	
LTOT	Channel 1, Channel 2,..., Channel N

-EOF-

3. F30 - Temporary likelihoods data set, fortran unit number 14.

This unit is accessed only in ITRA, i.e., when IFLAGM = IFLAGS = 0. The likelihoods for each class are computed and stored for each pixel on the 1st iteration of ITRA through the PUTPIX routine. The logical record format is

20A4. (This may be changed to binary). This file is accessed by GETPIX on subsequent iterations of ITRA.

4. F7 - Output signature data set, fortran unit 11.

This file contains the UHMLE signatures. They may be punched on cards or stored on disk for latter access.

V. Input Data Streams.

The input data stream, typically the card reader (fortran unit 5), consists of the following card images. All input parameter cards ignore the first 10 columns (except FMT). This allows comments or labels to be used. The deck setup is as follows:

1. Job control parameters

Parameter	Format
RUNID	(10x,A4)
M	(10x,I10)
N	"
L	"
FMT	(18A4)

2. Initial values of the mixture parameters

	ALPHA	(10x,7F10.4)
1st Class *	MUØ	(10x,7F10.4)
	SIG	"
Mth Class	MUØ	(10x,7F10.4)
	SIG	"

*each mean vector or covariance matrix must begin on a new card.

3. Iteration Control Parameters*

IFLAGA	(10x,I10)
IFLAGM	"
IFLAGS	"
MØDES	"
ITLIM	"
TØLA	(10x,F10.0)
TØLM	"
TØLS	"
EPSA	"
EPSM	"
EPSS	"
ITRPNT	(10x,I10)

*The iteration control block may be repeated as often as desired.

VI. Sample Deck Setup

The following is a sample job deck designed for use on the IBM OS/360 system. The first iteration phase iterates on the mean vectors only, assuring a fixed diagonal covariance and fixed equal proportions. This iteration configuration is used until the TOLM tolerance or ITLIM requirement is met. Then the second set of iteration parameters are read in and all mixture parameters (full covariance) are estimated. In the third iteration phase the μ's and Σ's are held fixed and only the α's are varied.

```
//UHMLE  JOB
//      EXEC   FORTHCLG
//SYSIN DD *
          <                                                  >
          <   INSERT THE UHMLE SOURCE DECK HERE              >
          <                                                  >
/*
//GO.FT11F001  DD  SYSOUT=B
//GO.FT12F001  DD  DSN=&&F10,UNIT=SYSDA,DISP=(OLD,PASS),SPACE=(TRK,1),
//       DCB=(RECFM=F,LRECL=80)
//GO.FT13F001  DD  DSN=&&F20,UNIT=SYSDA,DISP=(OLD,PASS),SPACE=(CYL,5),
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=7200)
//GO.FT14F001  DD  DSN=&&F30,UNIT=SYSDA,DISP=(NEW,PASS),SPACE=(CYL,5),
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=7200)
//GO.SYSIN  DD  *
          <                                                  >
          <  JOB CONTROL PARAMETER CARDS FOLLOW              >
          <                                                  >
RUNID     TEST
M                5
N                4
L             1000
(48X,4F4.0)
          <                                                  >
          <  INITIAL VALUES OF MIXTURE PARAMETERS FOLLOW     >
          <                                                  >
ALPHA     .2          .2          .2          .2          .2
MU  M1    19.27       17.11       29.24       34.39
SIG       2.48        3.27        5.40        0.68        1.02        1.54        -1.11
          -1.85       1.02        3.31
MUO F1    25.53       28.51       28.41       27.48
SIG F1    1.04        .94         2.02        .13         .04         1.07        .17
SIG       .28         .64         .95
MUO B1    24.23       24.73       32.57       34.45
SIG  B1   5.93        10.61       20.94       .99         1.68        1.46        -2.69
SIG       -5.83       .85         4.62
MUO S1    22.68       24.56       24.35        23.61
SIG S1    .76         .57         1.25        .46         .43         1.18        .50
SIG       .54         1.02        1.54
MUO G2    21.94       20.35       25.29       26.18
SIG G2    .64         .36         1.08        .04         .22         .63         .01
SIG       .25         .49         1.11
```

```
<                                                    >
<  ITERATION CONTROL PARAMETER SET 1 FOLLOWS         >
<                                                    >
IFLAGA          0
IFLAGM          1
IFLAGS          0
MODES           2
ITLIM          10
TOLA        0.0
TOLM        .5
TOLS        0.0
EPSA        1.
EPSM        1.
EPSS        1.
ITRPNT          0
<                                                    >
<  ITERATION CONTROL PARAMETER SET 2 FOLLOWS         >
<                                                    >
IFLAGA          1
IFLAGM          1
IFLAGS          1
MODES           1
ITLIM          10
TOLA        .05
TOLM        .1
TOLS        .5
EPSA        1.
EPSM        1.
EPSS        1.
ITRPNT          0
<                                                    >
<  ITERATION CONTROL PARAMETER SET 3 FOLLOWS         >
<                                                    >
IFLAGA          1
IFLAGM          0
IFLAGS          0
MODES           1
ITLIM          10
TOLA        .0005
TOLM        0.0
TOLS        0.0
EPSA        1.
EPSM        1.
EPSS        1.
ITRPNT          1
/*
//
```

VII. SAMPLE RUN OUTPUT

```
RUNID  'TEST'
M    =     5
N    =     4
L    =  1000
LTOT =  1000
FMT  = (48X,4F4.0)
ICORE IS        9507
```

JOB CONTROL PARAMETERS

```
**************************************************************************
ITERATION NUMBER     0     RUN ID  'TEST'
```

INITIAL VALUES OF MIXTURE PARAMETERS

	ALPHA	.2000	.2000	.2000	.2000	.2000
1						
	MU	19.2700	17.1100	29.2400	34.3900	
	SIG	2.4800				
	SIG	3.2700	5.4000			
	SIG	.6800	1.0200	1.5400		
	SIG	-1.1100	-1.8500	1.0200	3.3100	
2						
	MU	25.5300	28.5100	28.4100	27.4800	
	SIG	1.0400				
	SIG	.9400	2.0200			
	SIG	.1300	.0400	1.0700		
	SIG	.1700	.2800	.6400	.9500	
3						
	MU	24.2300	24.7300	32.5700	34.4500	
	SIG	5.9300				
	SIG	10.6100	20.9400			
	SIG	.9900	1.6800	1.4800		
	SIG	-2.6900	-5.8300	.8500	4.6200	
4						
	MU	22.6800	24.5600	24.3500	23.6100	
	SIG	.7600				
	SIG	.5700	1.2600			
	SIG	.4600	.4300	1.1800		
	SIG	.5000	.5400	1.0200	1.5900	
5						
	MU	21.9400	20.3500	25.3900	26.1800	
	SIG	.6400				
	SIG	.3600	1.0800			
	SIG	.0400	.2200	.6300		
	SIG	.0100	.2500	.4900	1.1100	

```
DELA =    .0000000D 00
DELM =    .0000000D 00
DELS =    .0000000D 00
```

FIRST ITERATION PHASE

```
IFLAGA =      0
IFLAGM =      1
IFLAGS =      0
MODES  =      2
ITLIM  =     10
TOLA   =      ,0000
TOLM   =      ,5000
TOLS   =      ,0000
EPSA   =     1,0000
EPSM   =     1,0000
EPSS   =     1,0000
ITRPNT =      0

ITERATION NUMBER        RUN ID  'TEST'

  1
    MU                 17,8031   16,5129   27,1694   31,3981
  2
    MU                 23,7007   27,0716   28,6527   28,1058
  3
    MU                 22,6907   24,8613   30,0646   31,1144
  4
    MU                 21,0216   23,3486   23,3769   22,8112
  5
    MU                 19,2719   18,2692   22,8665   23,8401
DELM =     ,33356190 01

ITERATION NUMBER     5    RUN ID  'TEST'

  1
    MU                 16,6778   14,8320   26,2050   31,1280
  2
    MU                 22,5021   25,2806   25,3615   24,7759
  3
    MU                 21,3214   22,2943   29,1891   30,9607
  4
    MU                 19,8427   21,8596   21,8481   21,2645
  5
    MU                 19,1461   18,0818   22,5252   23,4409
DELM =     ,48255680 00
```

SECOND ITERATION PHASE

```
IFLAGA =      1
IFLAGM =      1
IFLAGS =      1
MODES  =      1
ITLIM  =     10
TOLA   =     .0500
TOLM   =     .1000
TOLS   =     .5000
EPSA   =    1.0000
EPSM   =    1.0000
EPSS   =    1.0000
ITRPNT =      0

**********************************************************************
ITERATION NUMBER     1     RUN ID  'TEST'

      ALPHA                .2108      .2002      .1886      .2012      .1991
  1
      MU                 16.6639    14.8111    26.2000    31.1372
      SIG                 2.1491
      SIG                 2.5256     4.3368
      SIG                  .5766      .6716     1.5796
      SIG                 -.6004    -1.3074      .9739     2.7428
  2
      MU                 22.4559    25.2242    25.2934    24.7135
      SIG                  .8719
      SIG                  .7195     1.5809
      SIG                  .1527      .0281     1.0942
      SIG                  .1525      .1841      .6034      .9720
  3
      MU                 21.3160    22.2876    29.1754    30.9450
      SIG                 4.0012
      SIG                 6.8823    13.5315
      SIG                  .5259      .7899     1.1029
      SIG                -2.0998    -4.3828      .6186     3.4737
  4
      MU                 19.7642    21.7195    21.7747    21.1898
      SIG                  .6325
      SIG                  .3791     1.1063
      SIG                  .3202      .3385      .9569
      SIG                  .4302      .3833      .8357     1.4568
  5
      MU                 19.1452    18.0087    22.5618    23.5316
      SIG                  .5810
      SIG                  .2315      .9248
      SIG                  .0632      .1602      .5755
      SIG                  .0203      .1329      .4628      .9817
DELA =     .11360460-01
DELM =     .14010480 00
DELS =     .74084760 01
```

```
ITERATION NUMBER    4    RUN ID  'TEST'

    ALPHA                 .2061      .2010      .1931      .1992      .2006
  1
    MU                  16.7034    14.9441    26.1353    31.0456
    SIG                  2.3907
    SIG                  2.9303     4.8791
    SIG                   .6370      .9129     1.4492
    SIG                  -.7009    -1.3608      .8310     2.7143
  2
    MU                  22.4471    25.2265    25.2865    24.6933
    SIG                   .9040
    SIG                   .7286     1.5571
    SIG                   .1751      .0284     1.1312
    SIG                   .1915      .2184      .6583     1.0322
  3
    MU                  21.1581    21.9598    29.1732    31.0526
    SIG                  4.5883
    SIG                  8.1097    16.0966
    SIG                   .6068      .9891     1.0574
    SIG                 -2.4166    -4.9941      .4798     3.4870
  4
    MU                  19.7524    21.7273    21.7716    21.1802
    SIG                   .6253
    SIG                   .3892     1.0121
    SIG                   .3259      .3293      .9537
    SIG                   .4392      .4231      .8480     1.4683
  5
    MU                  19.1637    18.0153    22.5616    23.5397
    SIG                   .6039
    SIG                   .2613      .9172
    SIG                   .0578      .1689      .5851
    SIG                   .0143      .1715      .4705      .9680

 DELA =     .1020178D-02
 DELM =     .5515645D-01
 DELS =     .3150645D 00

 IFLAGA =     1
 IFLAGM =     0
 IFLAGS =     0
 MODES  =     1
 ITLIM  =    10
 TOLA   =      .0005
 TOLM   =      .0000
 TOLS   =      .0000
 EPSA   =     1.0000
 EPSM   =     1.0000
 EPSS   =     1.0000
 ITRPNT =     1

THIRD ITERATION PHASE

 ITERATION NUMBER    1    RUN ID  'TEST'

    ALPHA                 .2053      .2012      .1936      .1990      .2006
 DELA =     .7867705D-03

 ITERATION NUMBER    2    RUN ID  'TEST'

    ALPHA                 .2052      .2012      .1939      .1990      .2006
 DELA =     .1151414D-03
```

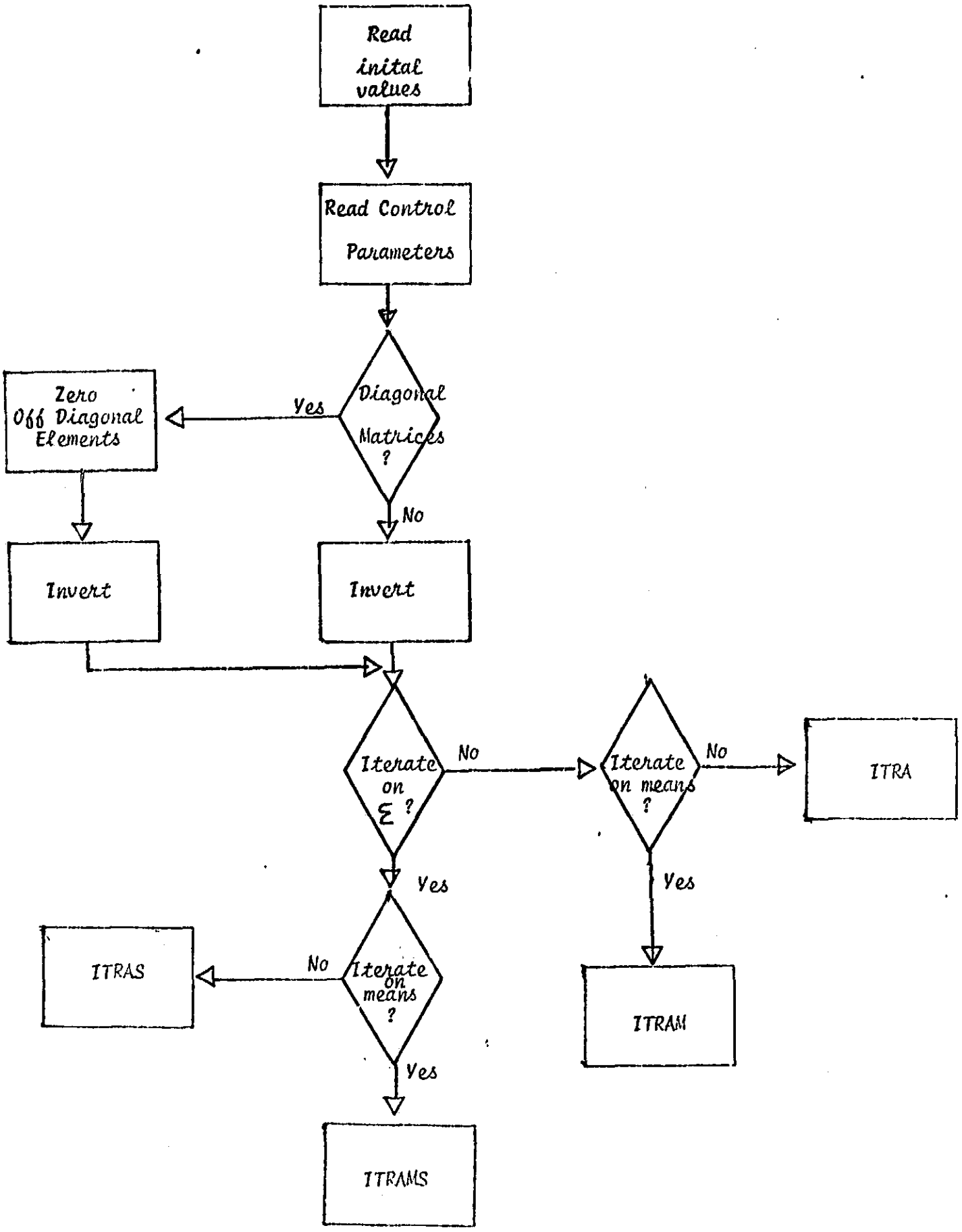
FINAL ESTIMATES PRINTED

```
**********************************************************************
ITERATION NUMBER     0     RUN ID  'TEST'

      ALPHA                  .2052      .2012      .1939      .1990      .2006
   1
      MU                   16.7034    14.9441    26.1353    31.0456
      SIG                   2.3907
      SIG                   2.9303     4.8791
      SIG                    .6370      .9129     1.4492
      SIG                   -.7009    -1.3608      .8310     2.7193
   2
      MU                   22.4471    25.2265    25.2865    24.6933
      SIG                    .9040
      SIG                    .7286     1.5571
      SIG                    .1751      .0284     1.1312
      SIG                    .1915      .2184      .6583     1.0322
   3
      MU                   21.1581    21.9598    29.1732    31.0526
      SIG                   4.5883
      SIG                   8.1097    16.0966
      SIG                    .6068      .9891     1.0574
      SIG                  -2.4166    -4.9941      .4798     3.4870
   4
      MU                   19.7524    21.7273    21.7716    21.1802
      SIG                    .6253
      SIG                    .3892     1.0121
      SIG                    .3259      .3293      .9537
      SIG                    .4392      .4231      .8480     1.4683
   5
      MU                   19.1637    18.0153    22.5616    23.5397
      SIG                    .6039
      SIG                    .2613      .9172
      SIG                    .0578      .1689      .5851
      SIG                    .0143      .1715      .4705      .9680
 DELA =     .11514140D-03
 DELM =     .55156450D-01
 DELS =     .31506450D 00
```

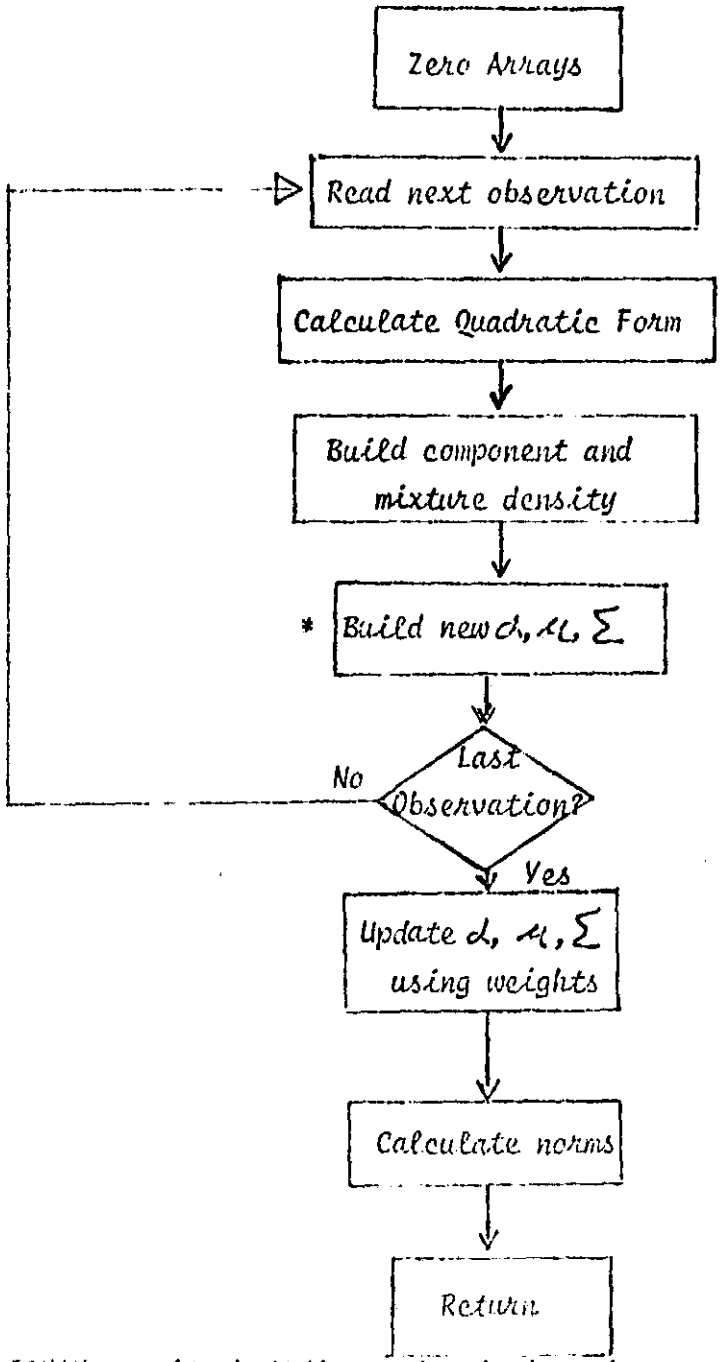
FINAL ESTIMATES PUNCHED (unit 11)

```
'TEST'      MLE OUTPUT SIGNATURES
ALPH          .2052      .2012      .1939      .1990      .2006
MU          16.7034    14.9441    26.1353    31.0456
SIG          2.3907     2.9303     4.8791      .6370      .9129     1.4492     -.7009
SIG         -1.3608      .8310     2.7193
MU          22.4471    25.2265    25.2865    24.6933
SIG           .9040      .7286     1.5571      .1751      .0284     1.1312      .1915
SIG           .2184      .6583     1.0322
MU          21.1581    21.9598    29.1732    31.0526
SIG          4.5883     8.1097    16.0966      .6068      .9891     1.0574    -2.4166
SIG         -4.9941      .4798     3.4870
MU          19.7524    21.7273    21.7716    21.1802
SIG           .6253      .3892     1.0121      .3259      .3293      .9537      .4392
SIG           .4231      .8480     1.4683
MU          19.1637    18.0153    22.5616    23.5397
SIG           .6039      .2613      .9172      .0578      .1689      .5851      .0143
SIG           .1715      .4705      .9680
```



Upon return from each subroutine the iteration tolerances are tested and when they are satisfied new control parameters are read.

FLOWCHART FOR ITRANS



ITRAN - omits building and updating sigmas at *

ITRAS - omits building and updating means at *